Living with a Star

Space Environment Testbed Program

Janet Barth GSFC

Dana Brewer HQ

Ken LaBel GSFC

Billy Kauffman MSFC

NASA Technology Provider/Partnering Workshop

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Outline

- **LWS Program Architecture – SET Program Role**
- **Management of Solar Variability Effects on Technology**
- **Goals of SET Program**
- **SET Program Plan**
- **Testbed Plan**
- **Workshop Goals**
- **Breakout Sessions**

- **Serendipitous Model for Science**
  - Fund basic science research solely on merit, and the results will filter down to application areas.
- **Living with a Star (LWS) Model for Science**
  - Users needs are used to influence the direction of science research, and the results will transform to application areas seamlessly.
- **Why the change?**
  - As our biosphere expands further into space, humans are increasingly vulnerable to the effects of solar variability (Space Weather) due to
    - increasing human presence in space,
    - increasing use of environmentally sensitive technologies, and
    - increasing dependence on space technology on Earth.

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Three Application Areas

Space Environment Testbed Program

A LWS Program element that completes science transition to users.
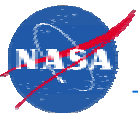
- **Human Radiation Exposure**
  - Space Station, Space Exploration
  - High Altitude Flight
  - Space Utilization & Colonization

- **Impacts on Technology**
  - Space Systems
  - Communication & Navigation
  - Ground Systems

- **Impacts on Life and Society**
  - Global Climate Change
  - Surface Warming
  - Ozone Depletion & Recovery

Living with a Star Program Architecture

- **Goal of LWS**
  - Develop the scientific understanding necessary for us to effectively address those aspects of the Connected Sun-Earth system that affect life and society.
- **LWS Elements**
  - Science Missions
    - Gather basic science data needed to achieve understanding
    - NASA/HQ science definition teams will include application scientists and engineers
  - Theory and modeling program
    - Defines environment at surface of spacecraft
  - Space environment testbed program
    - Defines environment interaction with spacecraft
    - Completes the transition from science to users
  - Close partnerships with DoD, DoE, DoI, FAA, and NSF
    - Under the aegis of the National Space Weather Program

Space Environment Testbed Program

- **Goal of Space Environment Test Program**
  - Develop the scientific understanding necessary for us to effectively address those aspects of solar variability that affect human presence or our use of technology in space
  - Extend our understanding to ground applications (neutron effects on avionic and ground systems)
- **How do we accommodate long and short term solar variability in planning capable, reliable, and cost efficient systems?**
- **Accommodations combine System Design and On-orbit Operation practices.**
  - Astronaut exposure to radiation – Spacesuit vs Storm shelter
  - Radiation effects on electronics – Spacecraft bus vs Instrument
- **Risk Avoidance vs Risk Management**

Technology Changes Drive Approach

- Technology changes
  - Commercial demand for electronics
    - Space market was 50% of market – Now is 0.1%!
    - Environment hardening efforts are overdriven by commercial demand
  - Demise of DoD investment in environment hardening efforts
  - Miniaturization - Generates environment soft technologies
  - Reduced costs – Design through operation phases
  - Demand for increased capability
- Spacecraft designers must use environment soft technologies
  - Capability – Emerging technologies, COTS, Low-power, High-speed, Miniaturization, Nanotechnology
  - Availability – COTS
- Trend is toward On-orbit Accommodation and Risk Management
  - Requires Space Weather forecasts

Environment Accommodations

- **System Design & On-orbit Operations practices require performance predictions.**
  - Need to characterize long and short term effects of the space environment.
    - **Environment models (LWS)**
    - **Validated ground test protocol**
    - **Validated performance prediction technique**
- **Reduction of risk requires design margins**
- **Accuracy of models determine magnitude of the design margins**
- **Large design margins erode capability in increased cost of design and operations**
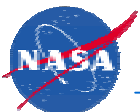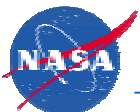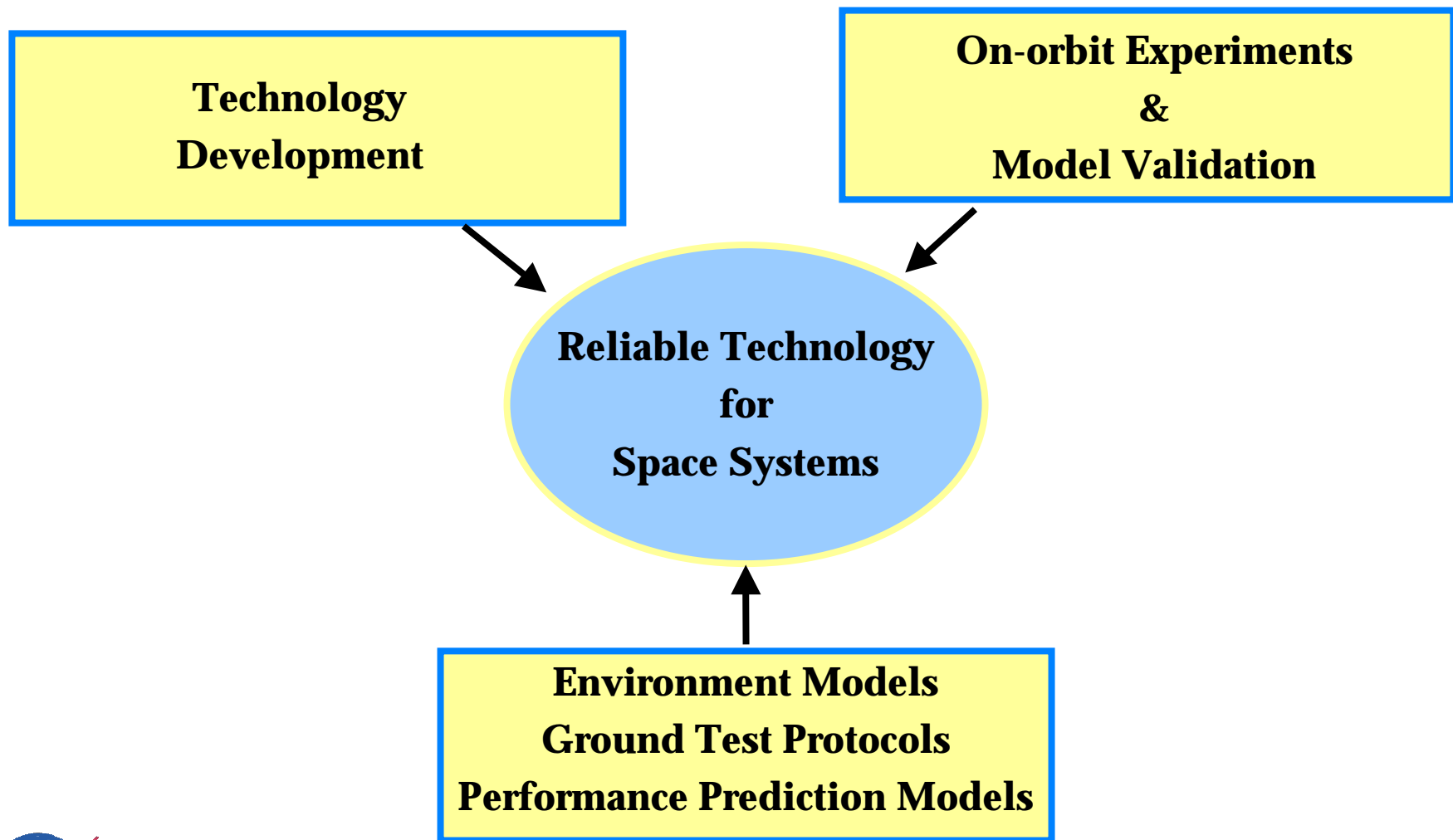
Goals of SET Program

- **Improve system engineering approach to mitigation of solar variability effects**
- **Implement accurate solar variability effects accommodations into spacecraft design and operations**
  - **Improved models increase capability (lower design margins)**
    - **Less mitigation overhead**
    - **Reduced shielding weight means reduced launch costs and increased payload**
  - **Improved models increase reliability**
- **Enable operation in higher radiation environments**
- **Increase technology infusion into Government/Industry programs**
  - **COTS, Low power, High-speed, Miniaturized, Nanotechnology**
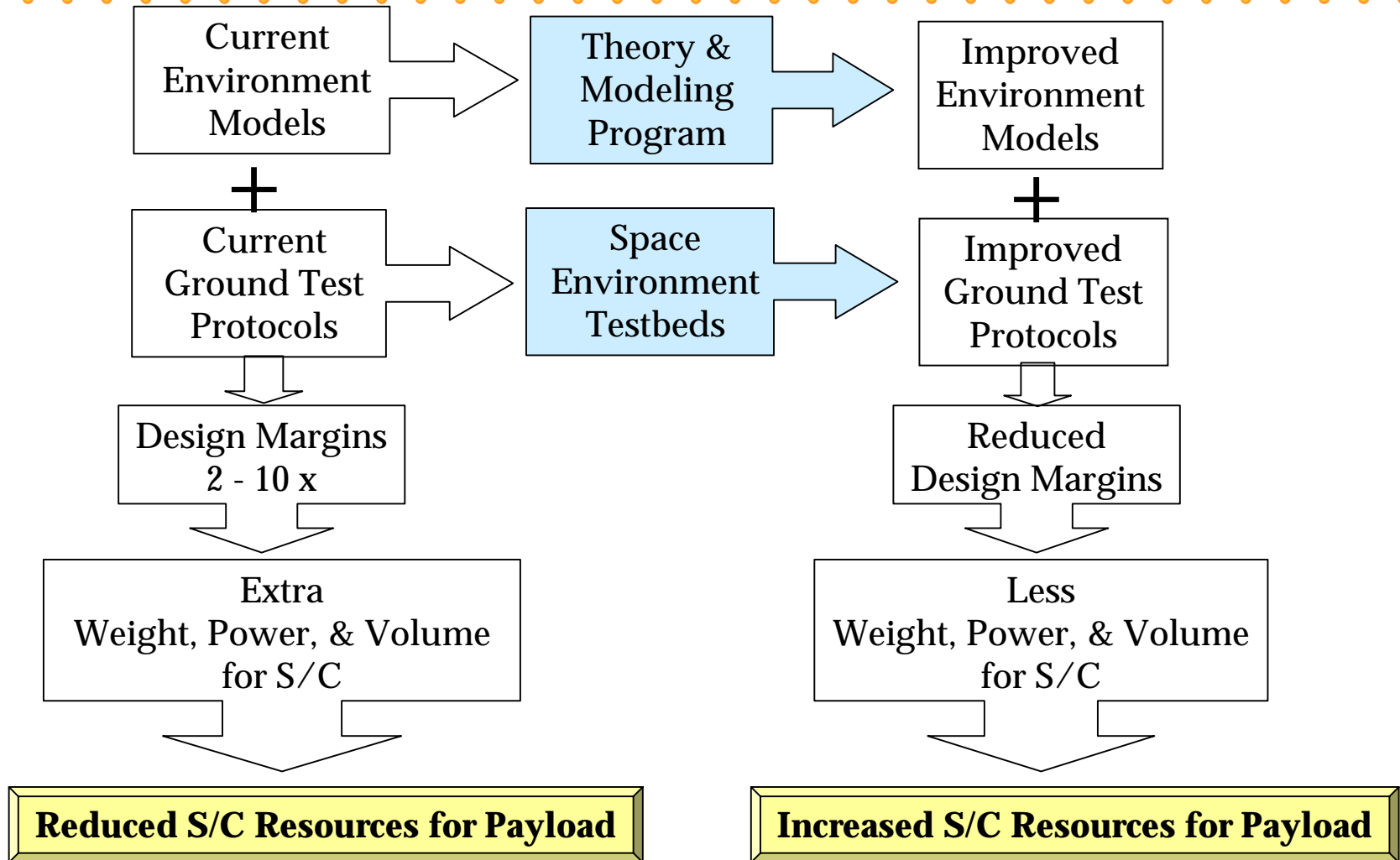
Technology Infusion for Space Systems

Technology Development

On-orbit Experiments & Model Validation

Reliable Technology for Space Systems

Environment Models

Ground Test Protocols

Performance Prediction Models

An SET Goal - Increase Capability

Current Environment Models $\rightarrow$ Theory & Modeling Program $\rightarrow$ Improved Environment Models

$+$

Current Ground Test Protocols $\rightarrow$ Space Environment Testbeds $\rightarrow$ Improved Ground Test Protocols

$+$

Design Margins 2 - 10 x $\rightarrow$ Reduced Design Margins

Extra Weight, Power, & Volume for S/C $\rightarrow$ Less Weight, Power, & Volume for S/C

Reduced S/C Resources for Payload   **Increased S/C Resources for Payload**

SET Program Tasks

- Understand solar variability effects on emerging technologies
- Establish ground test protocols for emerging technologies and commercial off the shelf components
  - Manufacturers do not qualify COTS for use in space
- Support development of prediction techniques
- Develop on-orbit Space Weather risk management techniques
- Validate environment models (LWS & others)
  - Environment Specification
  - Space Weather
- Validate ground test protocols & prediction techniques
- Demonstrate instrumentation and sensors for LWS Missions

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SET Program Implementation

- **Establish Definition Team**
- **Design modular approach to testbed design to capitalize on launch opportunities**
- **Fly orbiting testbed every 2 years – First in late 2003**
- **Hold bi-yearly workshops**
  - **Requirements definition & partnering**
  - **Presentations of results**
- **Leverage off other programs**
- **Fund NASA Research Announcements**
  - **Sensor development for tesbeds**
  - **Support experiment build for technologies of interest to NASA/Industry**
  - **Analysis of testbed data**
  - **Development of ground test protocols and prediction techniques**
- **First solicitation anticipated prior to the end of 2Q FY01**

LWS/Space Environment Testbed

- **Common support hardware and software to validate several sub-systems or components on orbit**
  - Each mission will include a suite of appropriate environment sensors (space radiation, plasma, etc.) based on the technology experiment needs and launch constraints.
- **NASA provides launch, on-orbit operation, and data return.**
- **Standard agreement with payload partners requires partners to provide ground test data, on-orbit data after reduction, and funding for integration.**
- **Partnering agreement is negotiable based on NASA interest and partner contribution to launch.**
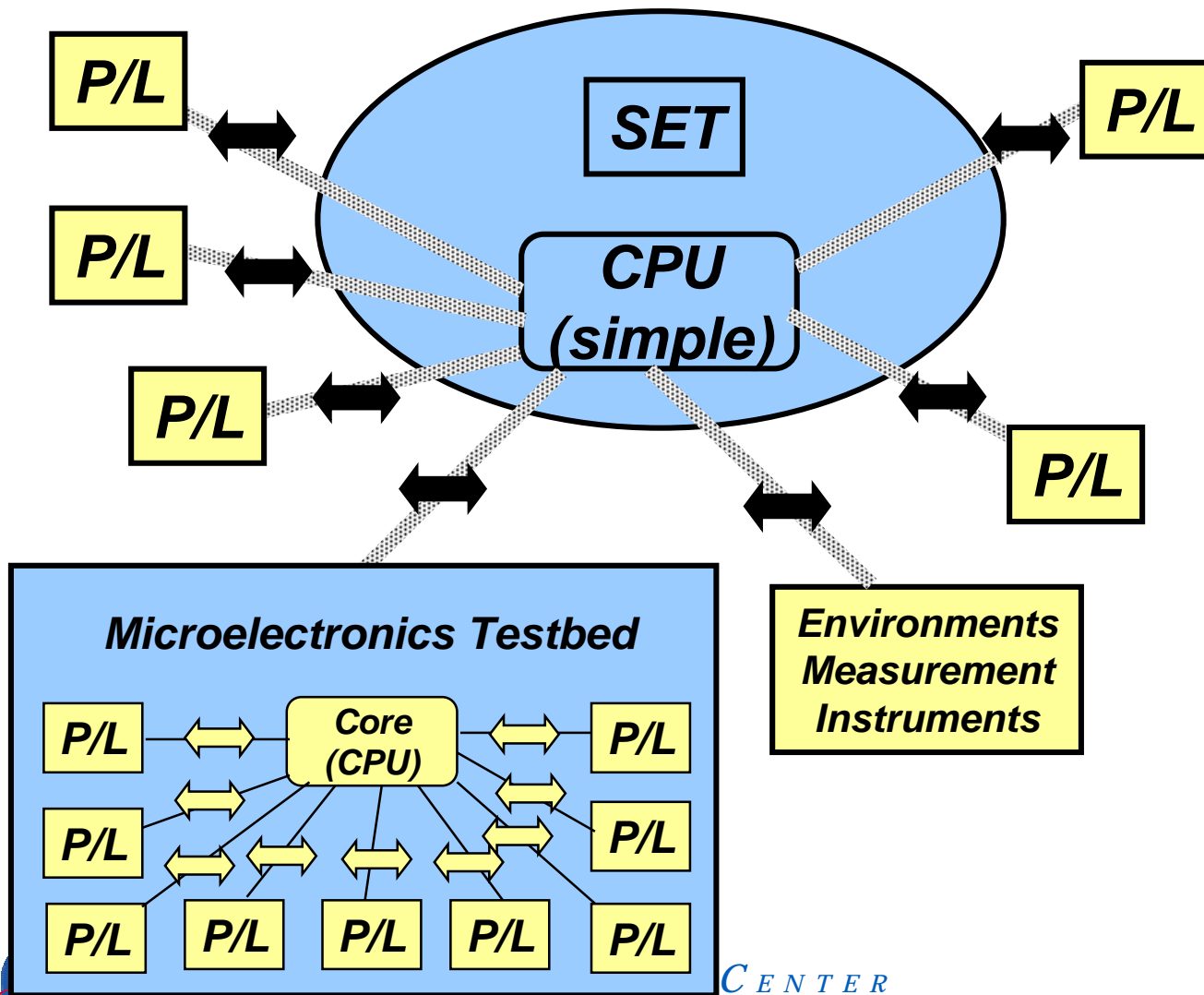
Previous Testbed Programs

- **CRRES – 18 deg, 360/36,000 km**
  - Microelectronics
  - Spacecraft charging
  - Particle measurement & dosimetry
- **APEX – 70deg, 254/3500 km**
  - Solar cell degradation
  - Solar cell charging
  - Effects of single particle hits on SRAMs and power MOSFETs
  - Dosimetry
- **MPTB – Highly Elliptical**
  - Microelectronics
  - Photonics
  - Poster presentation by Art Campbell of NRL with lessons learned and results
- **STRV – to be launched**

Testbed Concept

SET

CPU (simple)

P/L

P/L

P/L

P/L

P/L

P/L

Microelectronics Testbed

P/L Core (CPU) P/L

P/L P/L

P/L P/L P/L P/L P/L

Environments Measurement Instruments

Assumptions:

- **5 testbeds**
- **Launch: 2-year centers**
- **1-2 year life**
- **Weight: <150 kg**
- **Piggyback**
- **>1 launch vehicle**
- **Candidate payloads will meet the interface & fail safe**

Provided by Partners

Provided by the SET

C E N T E R

Experiments

- **Experiments take the form of materials, components, cards, sensors, or subsystems**
- **Technologies must show clear traceability to proposed criteria**
- **Potential experiment categories may include:**
  - **Microelectronics**
    - **Commercial (un-hardened)**
    - **Radiation Tolerant**
    - **Radiation Hardened**
  - **Photonics**
  - **Detector technologies**
  - **Materials**
    - **Degradation**
    - **Shielding properties**
  - **Mechanisms**
  - **Microelectromechanical systems (MEMS)**
  - **Subsystems**
  - **Space and induced environment tolerance methods**
  - **Spacecraft charging/discharging**
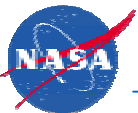
- **Task of environment characterization is shifted to science**
  - Increased ability to leverage ride opportunities
    - **Testbed experiments drive sensor requirements**
    - **Testbed experiments drive orbit requirements**
      - **Linear bipolars – protons**
      - **Single event effects – protons & heavier ions**
      - **Charging – electrons**
  - Environment characterization is done by appropriate science discipline
    - **Understanding in addition to characterization**
    - **Focused research program that looks to future needs**
- **Commitment to a long term space testbed PROGRAM**
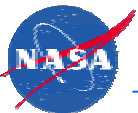
Goals of Workshop

- **Gather input for SET Program formulation**
  - We are at the beginning of our process.
- **Gather technology provider requirements for orbiting testbeds**
  - Define the scope of the program
  - Define carrier requirements
  - Assess technology availability and readiness
  - Understand the "criteria for success" for candidate technologies
- **Explore partnering opportunities for space testbeds**

Workshop Products

- **Identify Candidate Testbed Experiments**
- **Describe the State of the Art of the Technology**
- **Assess Timelines**
  - **Technology need**
  - **Technology readiness in 2003 to 2010 timeframe**
- **Establish the requirement for on-orbit testing**
- **Describe state of ground test protocol for the technology**
- **Describe experiment concept**
- **Identify on-orbit requirements of experiment**
- **Describe benefits**
  - **Missions**
  - **LWS Application Areas**
- **Identify Partnering Options**

Technology Breakout Sessions

Materials – Degradation & Shielding Properties

Ed Long - NASA/LaRC
Dave Edwards - NASA/MSFC

Spacecraft Charging

Dale Ferguson - NASA/GRC
Ralph Carruth - NASA/MSFC

Microelectronics

Sam Kayali - JPL
Dale McMorrow - NRL

Detector Technologies

Lee Feinberg – NASA/GSFC
Mike Jones – GSFC/Orbital

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LWS/SET Program Partnering

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SET Program Leveraging

- NASA Electronic Radiation Characterization Project – ground tests
- DoD ground test programs
- Space Environment and Effects Program
- New Millennium Program
- DoD technology development programs
- NASA technology development programs
- Seeking other partnerships

Partnership Guidelines & Variations

- **Guideline**
  - NASA & the Payload Partner should both benefit from the partnership
- **Variations from the partnering example are encouraged**
  - NASA and the partner continue to benefit from the partnership
  - Variations can include trading spacecraft systems for no data access, in kind contributions in lieu of funding, etc.
- **Partnership agreements can include:**
  - Cooperative agreements
  - Fee for service
  - Memoranda of Agreements
  - Space Act Agreements
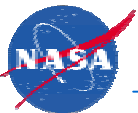
Three Options for Partnering

- **SET Program Partners: Partners contribute to the success of the SET Program**
  - **Agree on objectives and requirements**
  - **Participate in all Program aspects**
- **SET Partners: Partners contribute to the success of the SET**
  - **Retain separate requirements & objectives**
  - **Obtain allocation of spacecraft resources to achieve objectives**
- **Payload Partners: Partners contribute "payloads" in exchange for on-orbit operation, launch, & data return**
  - **"Payload" includes ground test data if appropriate, on-orbit data after reduction, & funding for integration and on-orbit operations**
    - **Variations in definitions of "payloads" are negotiable; "funding" can include in kind exchanges**

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